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The effect of silver salts and lignosulfonates in the synthesis of lignosulfonate-stabilized silver nanoparticles

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ABSTRACT

Water-soluble lignin derivatives – technical lignosulfonates (LS) – were used as reducing and stabilizing agents for a simple synthesis of silver nanoparticles (LS-AgNPs) in aqueous solution at room temperature during the reaction with silver salt. Three salts were used as the metal precursor: $AgClO_4$, $AgBF_4$ and $CH_3C_6H_4SO_3Ag$. The obtained silver colloids were analyzed by UV–Vis spectrophotometry, particle size distribution (NIBS method), transmission electron microscopy (TEM) and atomic force microscopy (AFM). Both the origin of the biomacromolecule and the type of silver salt contribute to the final size and shape of the LS-AgNPs. Therefore the selection of different reagents can be used to control the AgNPs size. As a possible application, the obtained silver particles were studied for their catalytic activity in the reduction of three dyes – C.I. Basic Blue 9 (methylene blue), C.I. Basic Violet 10 (rhodamine B) and C.I. Basic Orange 14 (acridine orange) – by sodium borohydride.

1. Introduction

Nanotechnology is the branch of science dealing with the manufacture and testing of structures in which at least one dimension is less than 100 nm. Such particles are called nanoparticles, and these can be classified in terms of their shape, source, and chemical composition. Nanostructures, in spite of their much smaller size, have the same physicochemical properties as their larger counterparts, but also have many other features making them suitable for a range of new applications in various fields.

Due to their unique properties, nanostructures of silver have been the subject of many studies and discoveries. Research conducted in the last decade has clearly demonstrated that the electromagnetic, optical, antibacterial and catalytic properties of metal nanoparticles are very much dependent on their shape and size, as well as the tendency to agglomerate [1–3].

Today there are many ways to prepare AgNPs, but there are three main groups of methods for their synthesis: chemical, physical and biological.

The most common, being very efficient and easy to perform, are the methods based on chemical synthesis. These include, among others, the chemical reduction of silver ions in aqueous and non-aqueous medium using hydrazine, borohydride or sodium citrate [4–6], as well as the radiation-chemical method, where the reduction process is initiated by solvated electrons generated by ionizing radiation [7]. As reducing agents of silver ions and/or stabilizers of the prepared metal nanoparticles, polymers such as poly(vinylpyrolidone) (PVP) and poly(ethylene glycol) (PEG) have been used [1,8].

Physical methods, which include among others evaporation/condensation and laser ablation, are characterized by the absence of chemicals in the solutions and by the obtaining of pure monodisperse nanosilver excellently suited to further applications. When laser

Table 1
Characteristics of lignosulfonate samples used in the study.

Sample	Wood type	Counter ion	Treatment
DP 839	Softwood	Na	Ultrafiltrated/desulfonated
DP 840		Ca	–
DP 841		Na	Ultrafiltrated
DP 842		Na	Oxidized
DP 843		Ca	Ultrafiltrated
DP 844	Hardwood	Ca	–
DP 845		Na	–
DP 847	Softwood	Ca	Cyanized
DP 849		Na	–
LS SA	–	Na	–

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ablation is used as a method for the preparation of AgNPs, it is easy to control the size of the obtained nanoparticles by varying the working wavelength of the laser [9].

The newest and least-known methods for the synthesis of silver colloids are biological and biochemical methods. These include processes using plant extracts – from leaves, stems, roots or seeds – as well as

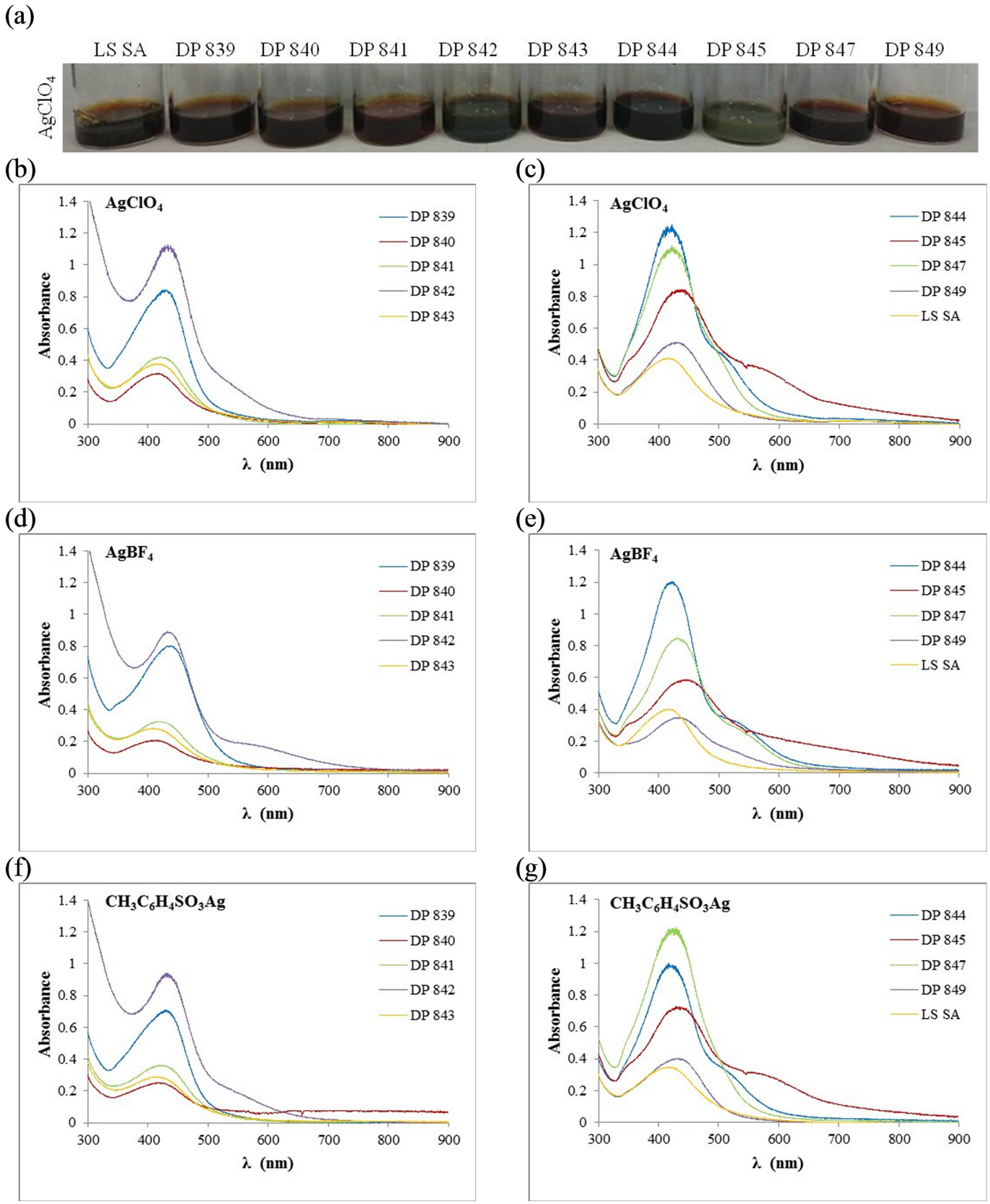

Fig. 1. Photographs of LS-AgNPs and UV–Vis spectra of silver colloids obtained with the use of (a–c) $AgClO_4$, (d–e) $AgBF_4$, (f–g) $CH_3C_6H_4SO_3Ag$ and different lignosulfonates.